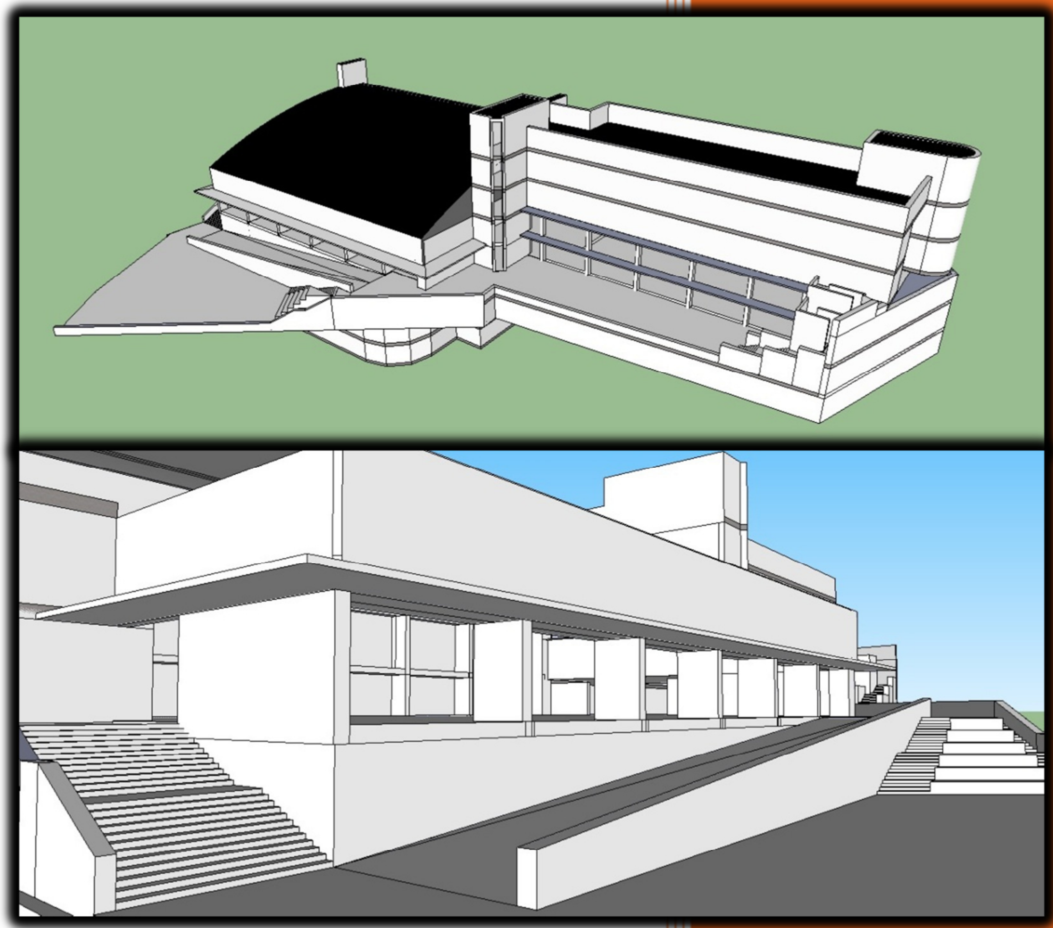
FINAL PROJECT



(P1: Sketchup 3D model © Devolder Lawrence)

NEW BUILDING AND DEVELOPMENT OF THE ENVIRONMENT IN THE CAMPUS OF ALCOY.

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Universidad politécnica de Valencia

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Contents

Introduction

This thesis is made to finish my career as Erasmus student in “Ingeniería de edificación” at the Polytechnic University of Valencia (UPV).

I’m a Belgian Erasmus student from the campus KAHO SINT LIEVEN-DIRK MARTENS AALST, and came to Valencia in February 2013 to terminate the last year of my studies.

Like every other final year student I had to make a final project about a construction site which we had to visit weekly.

My construction site was situated in Alcoy at 114km from Valencia. I made my final project about several subjects.

First of all I made an explanation about every phase that happened to make the construction complete. From these phases I picked one subject to explain more detailed, namely the construction of the cellar.

To involve the fact that I’m an Erasmus student I also made a comparison between Belgium and Spain.

For me this final project was a very interesting experience and I learned a lot new things about the way of building in Spain. In this way I can say I completed my goal which I had set before my arrival.

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BELGIUM

1. Objectives

The main goal I wanted to reach with making this final project in Spain was to learn about the way of construction in another country. In this way I was able to expand my knowledge and vocabulary in the world of construction.

I knew it wouldn't be easy due to the language factor, but the competence I wanted to reach during my stay at the construction site and during the work on this final project was to express myself as clear as possible in Spanish at the construction site and in English in this final project.

In this way I was able to learn a lot technical words in both English and Spanish. I'm sure I will be able to use this knowledge in the future.

2. Methodology

Once every week I was able to go to the construction site for an entire day to collect information about the project. I gathered that information by studying the project documentation provided the first days, by doing visits on the construction site itself to see the processes being done, by taking pictures from important phases, asking questions to both workers and supervisors, by making a 3D model in Sketch Up to understand the geometry of the project, and also by making visit reports from every visit I made to the site. By gathering all that information I achieved my objectives to learn about the way of construction in Spain and to expand my technical vocabulary.

The project documentation contained a lot important data to understand the project. By data I mean, dimensions, materials, plans …
Of course that was not enough, because not everything was done like explained in the project documentation. For example; they mentioned the construction from steel structures, which eventually they won't build.
For that reason it was necessary to ask a lot questions about the project.

By taking pictures from the process I was able to visually see the aspects explained in the project documentation.
For me the most interesting part to get to understand the project was to make a 3D model. To make this model I had to study all the plans to give dimensions to the project. Like this I got a general view from the geometry.

After every visit I made a report. These reports contain a general view from the progress made during my stay, explained by use of photos and drawings.
I have added these reports at the end of the project.

I'm able to divide the phases into 3 different parts. First the part which contains the phases done before my visits started, the second part with the phases done during my stay at the construction site and the third part with the phases still to finish or to be done after the determination of my visits on 21may.

1) Phases done before my visits:
   - Soil excavation
   - Diaphragm walls
   - Cellar
   - Floors
   - Concrete structures (columns)
   - Wood structures (Roof sports hall)
2) Phases done during my stay:
   - Staircases
   - Facades
   - Rooftop cover
   - Installations (water, ventilation,...)
   - Bathrooms (Tiles)
   - Windows
   - Chimney
3) Phases still to finish or to start after my visits:
   - Facades
   - Bathrooms (Tiles)
   - Windows
   - Electricity
   - Environment

The phases done before my arrival at the construction site were the most important to study, because I couldn't see the progress from them. Like I explained before, one part of this final project goes about the construction of the cellar. It was needed to study this part very good to understand the construction of it.

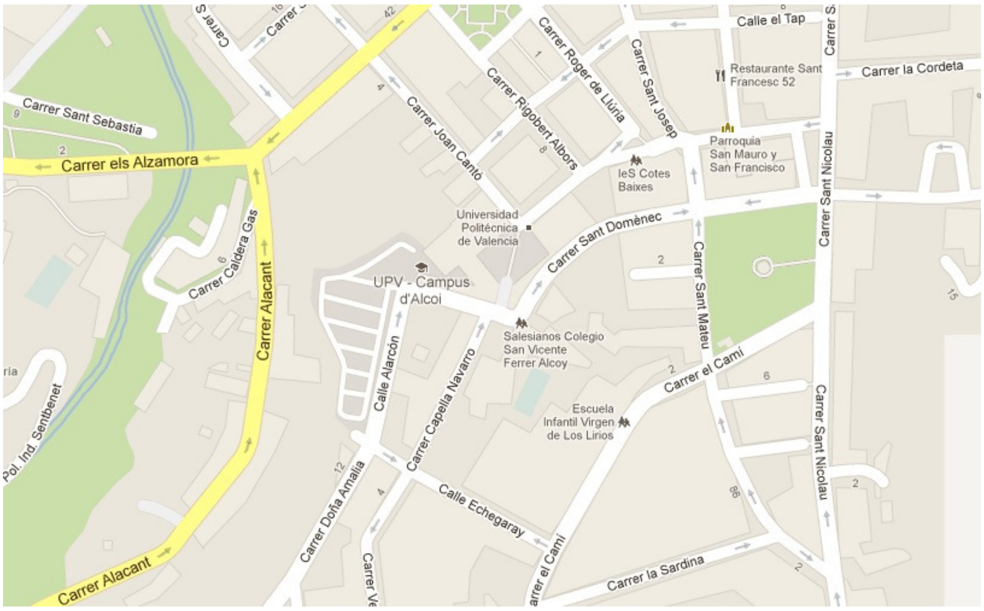
Most of the phases I saw developing are still in progress. They estimated the project to finish in 3 months.

3. Construction site

The complex is being built for the Polytechnic University of Valencia (UPV), which provided the budget for the construction of a new building as well as the development of their environment, to expand the campus of Alcoy.
The parcel contains a total area from 3819 m² usable space.

The contract has been divided into two lots, the first one for the construction of the building and the development of the environment, which has been awarded to Acciona Infrastructuras SA, while lot 2 was awarded to Fulton SA for the installations in the building. The award to get the contract has been processed through a regular and open procedure.

Lot 1: Civil works: Main contractor: Acciona Infraestructuras S.A.
Lot 2: Installations. Main contractor: Fulton S.A.



(P2: Situation map Alcoy)

This project, categorized as "campus recreation area", is budgeted in total about 6.775.548, 11€. The project, which started on the 4th of October, includes the construction of an underground parking area with 250 parking spaces and recreational area for the campus, which includes gardens, a gym, an indoor sports hall, changing rooms, multipurpose space that can be used for summer school or other similar activities along with the urbanization of the environment, in what is known as the hill of La Beniata.
The performance takes place at the area located behind the building Carbonell, right where the parking area was.

In total there will be 13,500m² of floor area, largely used underground since there are three cellar floors used as parking area. The project has been designed by the architect José Vicente Jornet, who won the contest organized by the Polytechnic University of Valencia. According to the technical building code this building contains construction code c2.

My last visit was on 21 may and until then they have completed the entire concrete structure in absence of the termination of the main vertical communication core: Staircase 1.
In block 2 they have completed all concrete structures and the zinc plated roof coverage on top of the laminated wood structure in absence of the areas where the chimneys will be situated.

Current photograph of the work:

(P3: Current photograph of the work 21/05/2013)

4. Building description

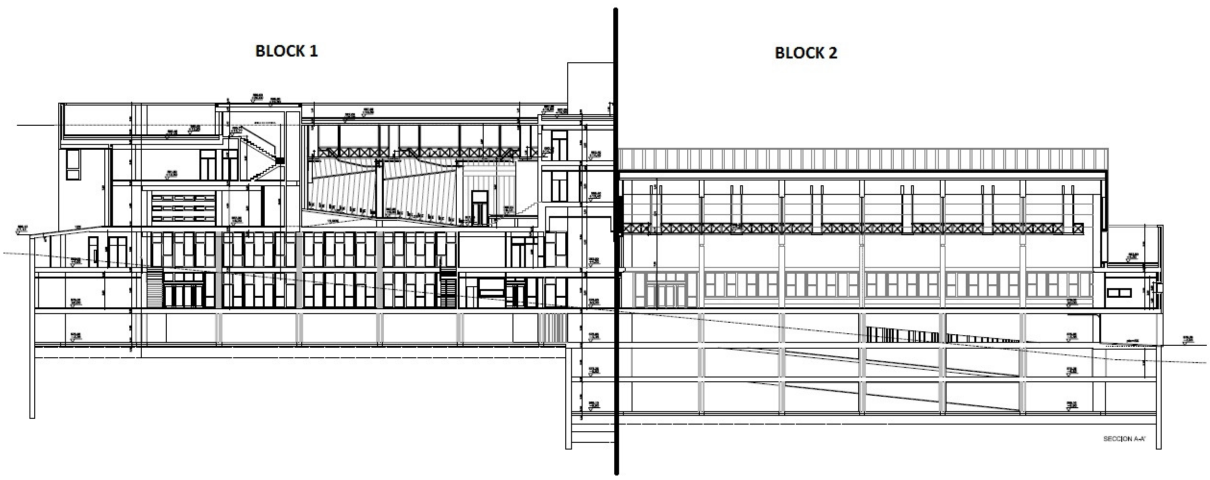
The project can be split up into two different blocks, because there is a difference in depth of the cellar. Total superficies: 3819m²
The uses of the blocks are:

Block 1:

- Cellar floor (-1): Parking (58 places) → 1626.22m²
- Ground level (0): Gym, monitors office, changing rooms, toilets, lobby. → 988.01m²
- First floor (+1): Gym, reception, changing rooms and monitors office. → 735.50m²
- Second floor (+2): Summer school, multipurpose spaces, walkways, toilets, offices. → 927.76m²
- Third floor (+3): Offices, laboratories. → 481.00m²
- Rooftop: Installations → 168.80m²

Block 2:

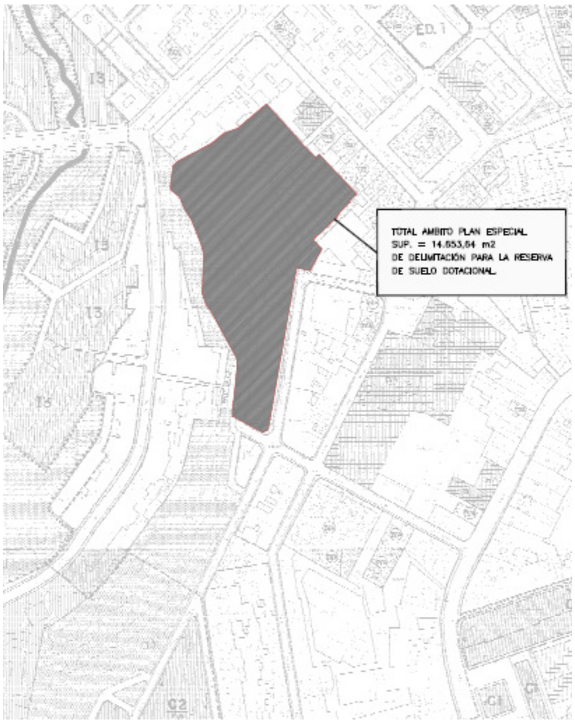
- Cellar floor (-3): Parking (71 places) → 2354.38m²
- Cellar floor (-2): Parking (67 places) → 2331.36m²
- Cellar floor (-1): Parking (55 places) → 2195.13m²
- Ground level (0): Sports hall. → 1525.48m²



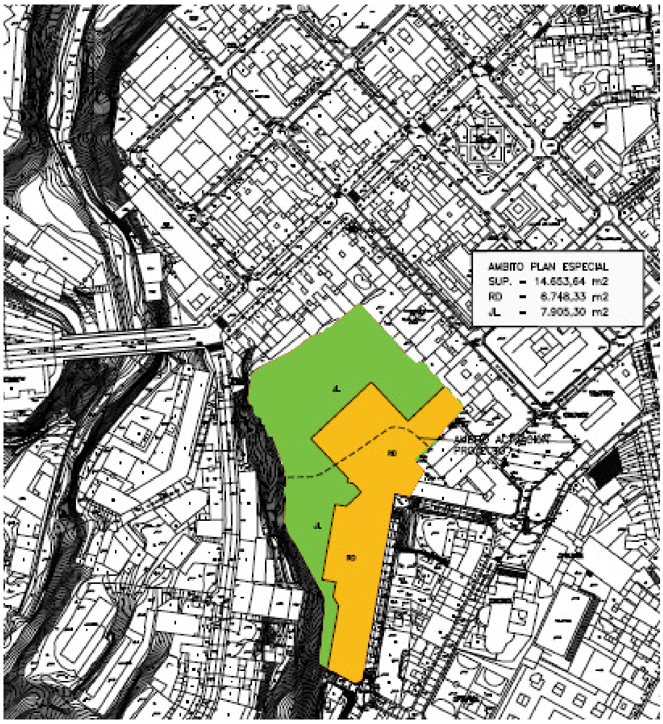
(P4: Section AA)

5. Site installation

First of all I want to show where the building area is situated in the urbanization of Alcoy. Like you can see in the following images, the area contains a lot more space than the actual constructed area. These areas will be used as recreational space for the campus from Alcoy (tennis court, park …).



(P5: Total area)

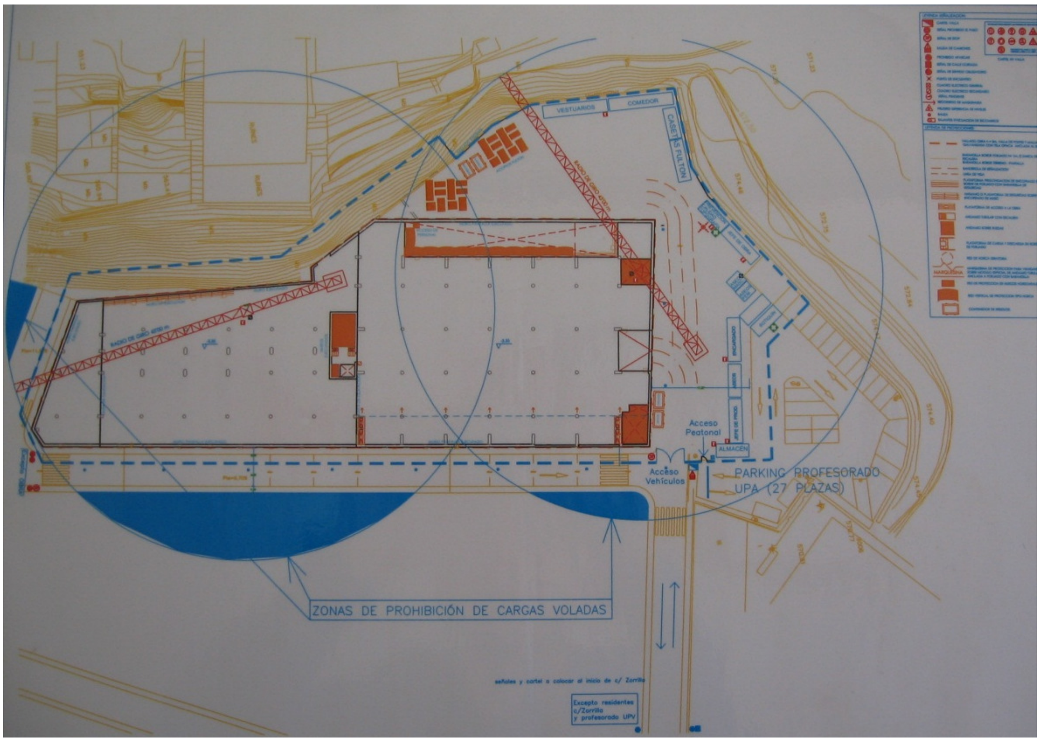


(P6: Urbanization)

As you can see on the right image, there are a lot of buildings in the surrounding areas. They had to keep these building in count during the construction, because this makes the useable space for the transport of materials limited.

Another part I had to talk about during my final project was the site installation during the time of my stay. Before any works were done, during the preparation of the construction site they had to make an installation plan. This plan contains the exact place of all work sheds, bathrooms, fences, tower cranes, storage areas, access points to the construction site …

This has to be prepared well, so it can fit during every phase.
For example it's very important to put the dimension from the tower cranes and the areas where it can't be used. In the next image this part has been colored in blue.
During my entire stay the storage area hasn't changed. This storage area was located at the best place, because since there it was very easy to get access to the project, and since there they were able to use the constructed ramp situated in block 2 to distribute the materials. More important is that since that place the materials were in nobody's way.



(P7: Site installation plan)

During my stay they mostly used the storage area for the storage of bricks.
At the situation plan you can see 2 tower cranes. When i started my visits one of them (block 2) was already removed. This means that they couldn't take the materials anymore with the crane. So they distributed the materials with a pallet truck.

(P8: Storage, hollow bricks)

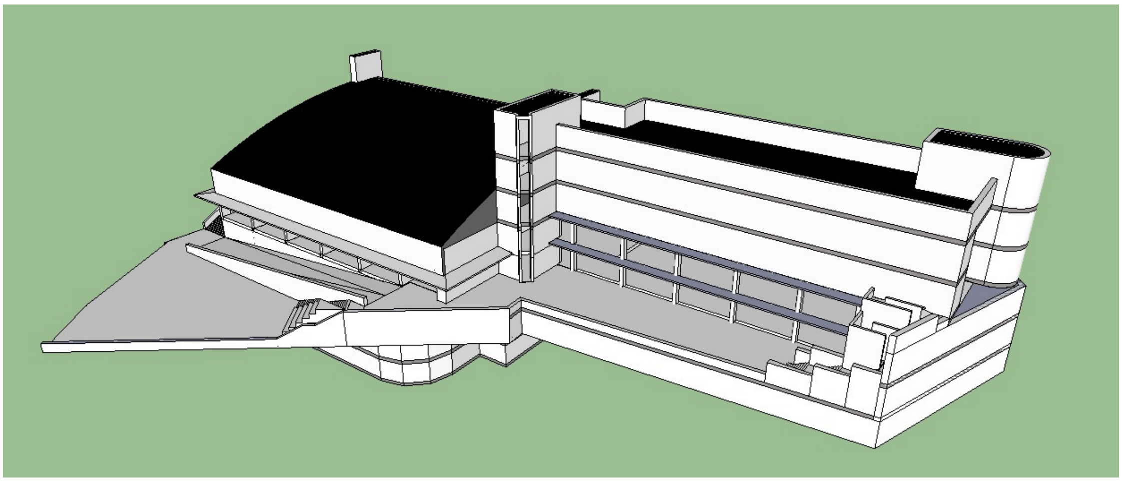
I also managed to see several times how they delivered concrete and mortar.
They deliver the mortar in several big containers, who later are distributed to the several areas where needed.

(P9: Delivery of concrete)

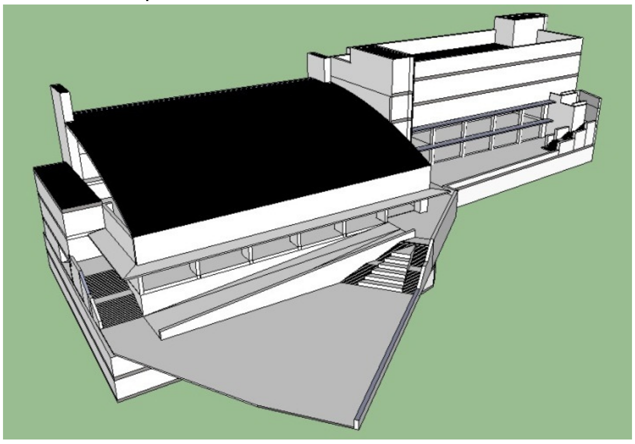
6. Sketch Up model

To make the project more visual I made a 3D model, using Google Sketch Up.
I had never used this program before, so I searched tutorials on internet to learn how to use it. After a whole weekend I finally finished my model.
Since that time I started using Sketch Up more times for other subjects I follow at the UPV campus.

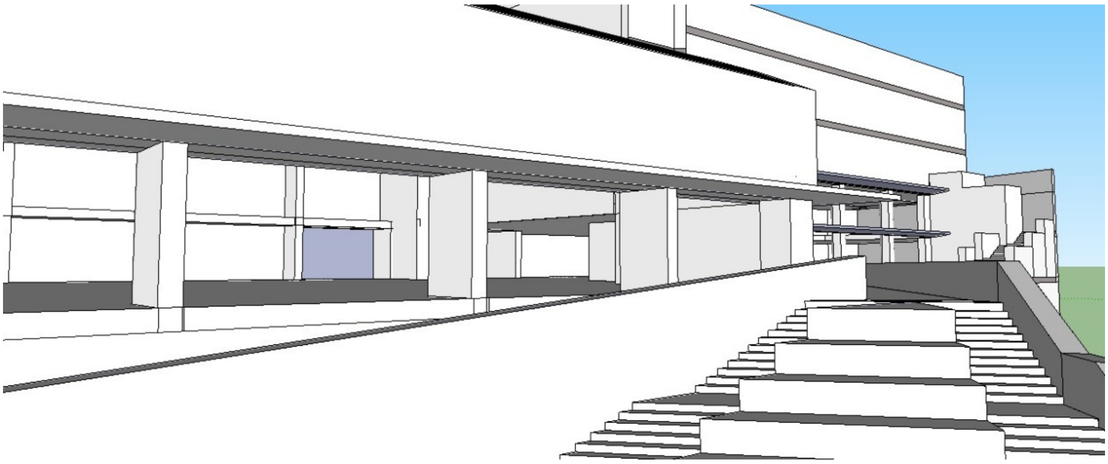
At the construction site they were very positive about this 3D model and they asked me if they could use it to win a price with the company Acciona.
I was very pleased to hear that and gave my model with pleasure.
This is the result:



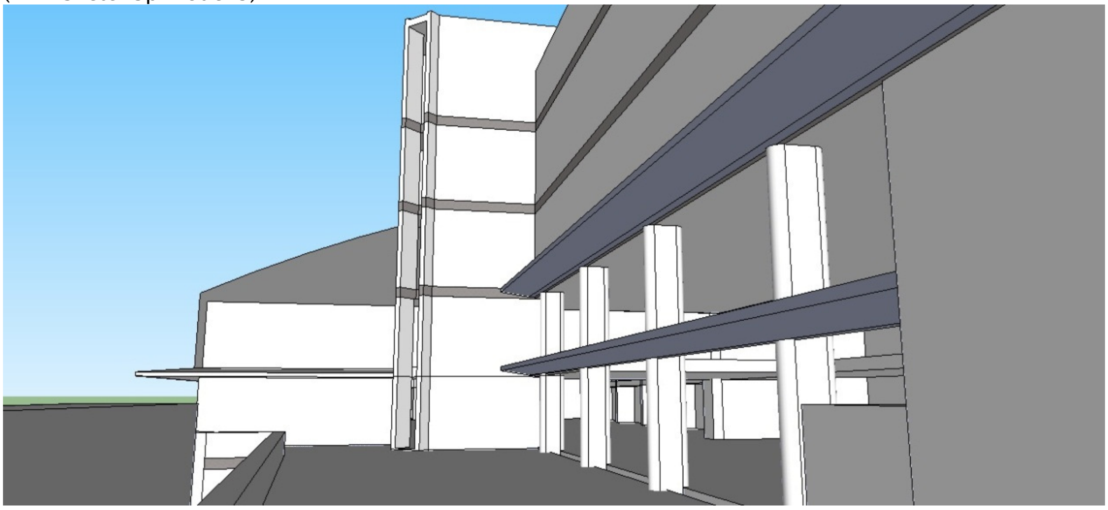
(P10: SketchUp model 1)



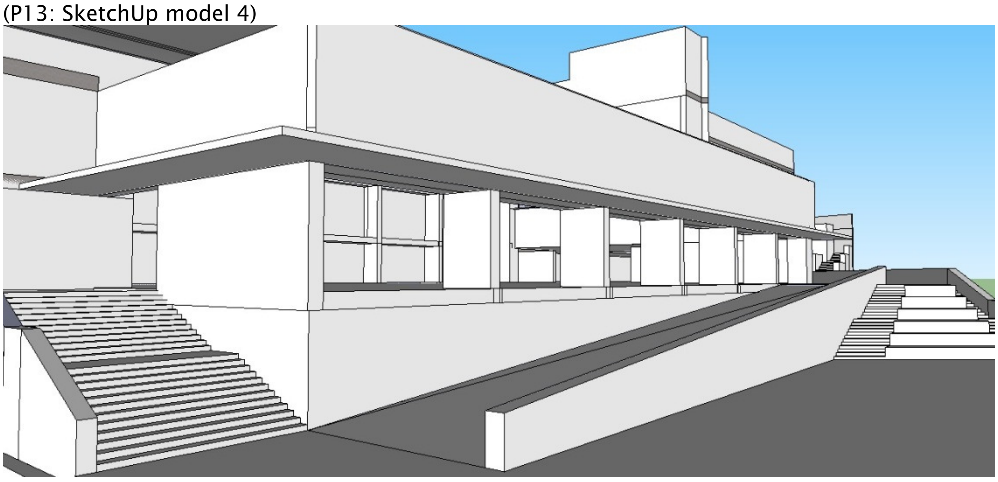
(P11: SketchUp model 2)



(P12: SketchUp model 3)



(P13: SketchUp model 4)



(P14: SketchUp model 5)

7. Phases

7.1. Earthworks

7.1.1 Task

The excavation of the ground took place upon different levels according to the dimensions of the project, and was done in several stages, because of the great depth that had to be excavated on the hill.

The first task that had to be done was to remove all the asphalt and pavements from the existing parking area (25cm) by use of excavators with jack hammers.

To prevent the surrounding area falling into the working site they have built reinforced concrete diaphragm walls situated at the edges of the project. These concrete walls were built before any excavation of the ground was done and take use as the foundations of the building. (7.2 Foundations)

(P15: Removal of the asphalt and pavements)

(P16: Excavation of the ground)

To get access to the different levels with the heavy machinery, they had to build slopes that make this process easier. In this way it was possible to remove the ground out of the project by use of dumpers.
The excavation of the ground goes together with the geotechnical study. To know if there will be water found during the excavation they put a piezometer tube (PVC 75mm) into the ground. According to the geotechnical study from the project there was no water found because the project is situated on a hill (Ca. + 570m).

7.1.2 Equipment

- <u>Trucks</u>:
  Working equipment used for transport of material.

(P17: Truck with top cover)

In Spain there is a law that says trucks need a top cover when leaving the construction site.

- <u>Excavators</u>:
  Excavators are heavy construction equipment with a structure capable of rotating at least 360 ° used for excavating ground by the action of the bucket attached to a group formed by boom and arm.

(P18: Excavator)

(P19: Excavator with its several parts)

- **Excavator with jack hammer:**
  The Backhoe with Air Hammer is construction equipment that is used in earthmoving operations on the one hand, cargo operations and, on the other, to break down certain elements.

(P20: Backhoe with jack hammer)

- **Vibratory compactor:**
  The vibratory Compactor is construction equipment used for compacting ground or asphalt after being spread by a vibratory roller.

(P21: Vibratory compactor)

7.2. Foundations

7.2.1 Task

The foundations of the project are made by reinforced concrete diaphragm walls that also make the coverage of the different cellar floors and prevent the surrounding ground to fall into the working area during excavation.
These diaphragm walls tend to be used for retaining very deep excavations as they are able to take very high structural loads.

- Width: 0.50m
- Concrete: HA-30/F/IIa + QA
- Steel: B500 SD

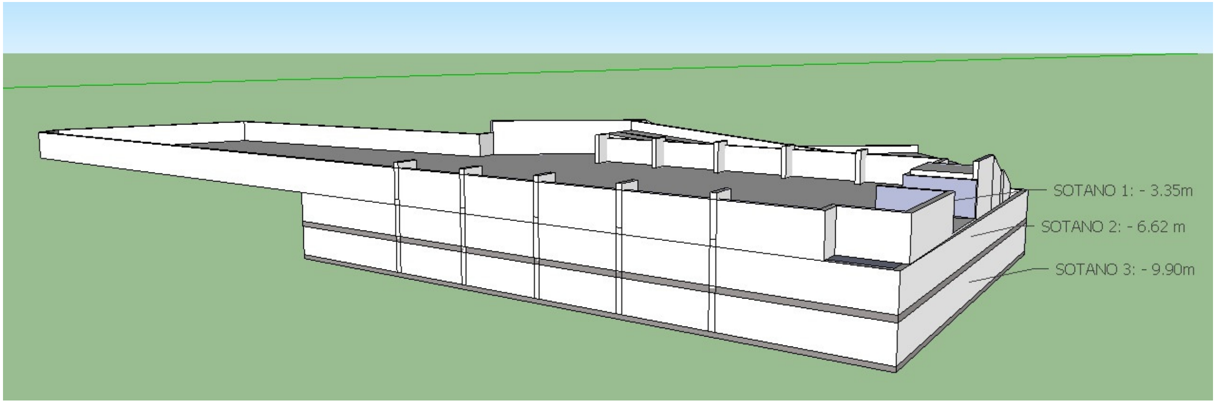
Because of the situation of the construction site they made use of these walls in the project. The construction site is situated on a very steep slope next to a valley. The use of these walls was the best option, because other solutions would have to be twice as deep as these ones. The great length without a lot joints made it interesting to use these walls on the slope and valley.

(P22: Diaphragm walls)

Some advantages of the diaphragm walls are:

- Can be used in very unstable soil profiles below the water table.
- Can be installed to considerable depth.
- Designable to carry vertical loads.
- Construction time of Basement can be lowered considerably.
- Economic and Positive solution for large deep basement in saturated and unstable soil profiles.
- No vibration during installation.

The project contains two different levels of excavation because of this steep slope and valley. This is why the building can be split up into two different blocks. Block one, situated on the highest point, contains only one level under the ground level (-3.85m). Block two, the lowest point, contains three cellar levels (-10.30m).



(P23: Sketchup 3D model cellar levels © Devolder Lawrence)

The process couldn't be done in one fluid time, so they have split up the work into different areas. The process contains the following tasks:

1) <u>Guide wall construction:</u>
   Concrete walls used to guide the excavator into the good position to remove the ground in a straight line. (0.80 * 0.20)

(P24: Guide walls)

2) <u>Creation of the reinforced concrete walls in block 1(diaphragm wall):</u>
Excavation of the ground between the guide walls reinforced with steel nets and filled with concrete. Block one has also been split up into several areas. The maximum depth of the wall is 14.40m and the width is 0.50m.
To prevent the walls from collapsing due to the surrounding ground pressure they anchor them in one line into the ground.
These anchors are constructed by use of hollow steel tubes drilled into the wall and filled with concrete injected under pressure to create a plug.

(P25: Diaphragm walls being filled with concrete)

3) <u>Creation of the reinforced concrete walls in block 2:</u>
This is the same process like in block 1.
4) <u>Foundation floors:</u>
After the execution of the cellar walls they reinforced the floor with concrete. The foundation floor is created directly on to the ground and has a height of 80cm.

(P26: Foundation floors)

7.2.2 Equipment

- <u>Diaphragm wall excavator:</u>
  Work equipment designed to carry out the excavation of diaphragm walls.

(P27: Diaphragm wall excavator)

- <u>Concrete mixer:</u>
  The concrete mixer is used to transport the concrete made on a concrete mixing plant, over long distances.

(P28: Concrete mixer)

- <u>Concrete pump:</u>
  The concrete pump truck is used to lift the concrete to heights above 30 m. This is done by a crane arm pumping up the concrete to the desired height. In this case the pump was used to reach a far distance.

(P29: Concrete pump in action)

(P30: Concrete pump)

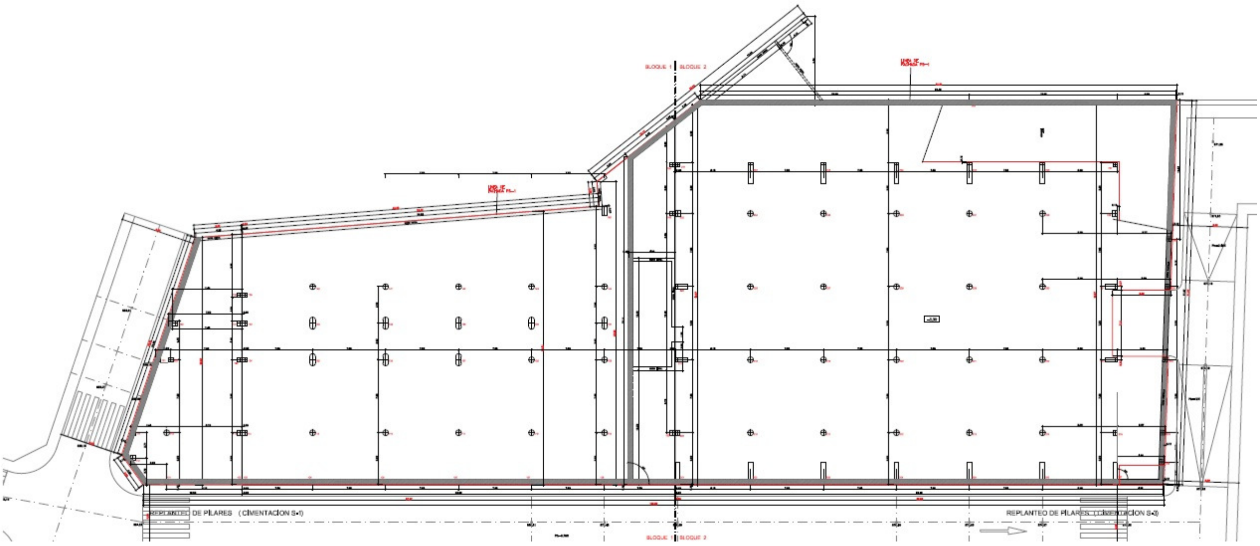
7.3. Structures

7.3.1 Reinforced concrete structures

- Columns:

After the foundation floors were done they started to construct the columns. These columns are the main structure/skeleton of the building and guide the weight towards the foundations. All columns were made in situ. To make the connection with the floors they made provisions while constructing the floors, by putting reinforcements into the concrete.

(P31: Reinforcement provided in the floors)



(P32: Situation plan of all columns in level -1)

There are different types of columns, which mean that there are different types of formworks/molds.

- **Round columns:**
  Materials: Steel



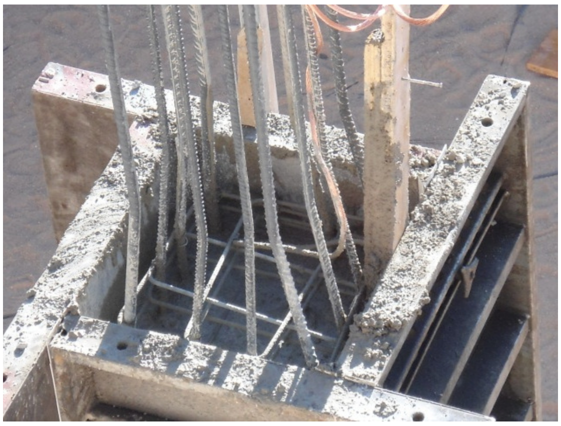
(P33: Reinforcement) (P34: Round mold) (P35: Round column)

- **Oval columns:**
  Materials: Steel and panels



(P36: Reinforcement) (P37: Oval mold) (P38: Oval column)

- **Rectangular columns:**
  Materials: Panels


(P39: Reinforcement) (P40: Rectangular mold) (P41: Rectangular column)

- **Inclined columns of great height:**
  Inclined columns, 13m high to support the wooden beams from the roof. By use of scaffolding for each pillar.


(P42: Molds) (P43: Inclined columns of great height, sports hall)

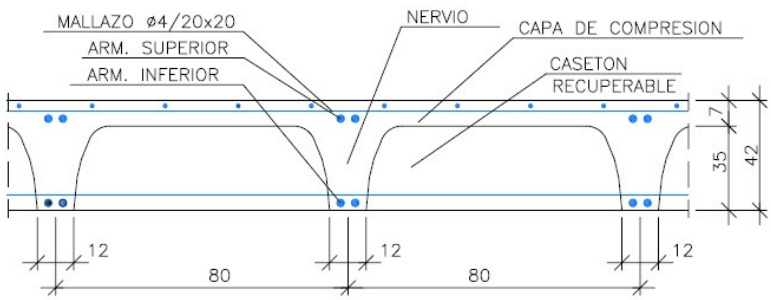
- Slabs:

The next step in the process was to construct the floors/horizontal structure, so they could continue building upwards. In this project there are different types of floor constructions.

- **35+7cm:**

  35 + 7cm is the dimension of the constructed floor.
  This floor type was only used in the cellars.
  This is a reticular floor structure from 80*80cm and a height of 35+7cm, constructed with the use of recoverable plastic coffers (80*80*35).

  After the plastic coffers were set in place they added a compression layer on top of 7cm of concrete (HA-30/B//IIa). The space between each coffer is called a nerve and is also filled up with concrete and reinforcements.

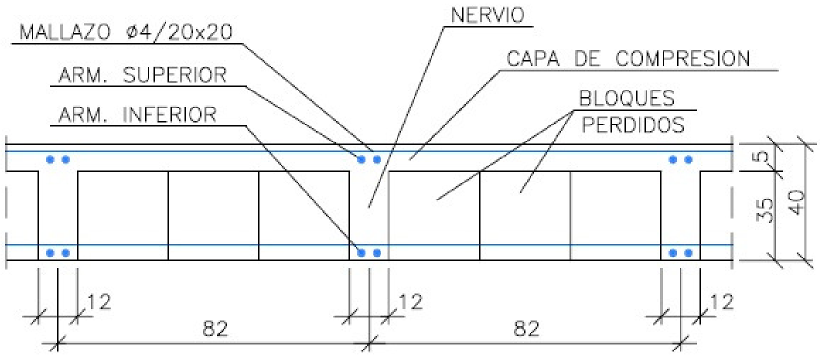


(P44: Detail 35+7cm)

(P45: Plastic coffers set in place)

- **<u>35+5cm:</u>**

  35 + 5cm is the dimension of the constructed floor.
  This floor type was used on different floor levels.
  Just like the other floor used in the cellar is this a reticular floor structure with reinforced concrete nerves.
  The only difference with the other floor is the use of material.
  Instead of using plastic coffers, they use concrete blocks (70*23*35).
  The blocks are placed three by side and can't be recuperated. The compression layer contains 5cm height (HA-30/B//IIa).



(P46: Detail 35+5cm)

(P47: Concrete blocks set in place)

- Concrete walls:

The building contains a big amount of reinforced concrete walls; each of these walls has its own visual aspect. In total there are 3 different types of surfaces.

- **Reed structure:**
  This structure was used in some parts of the cellar, because the cellar walls couldn't be constructed till the good level. To have the same texture like the cellar walls, they used reeds in the mold.
  Like this the surface looks milled.

(P48: Reed structure molds)

(P49: Reed structure surface, cellar)

- **Wood structure:**
  There are several places where they used wood in the molds; this makes the concrete wall look like a wooden wall. These molds can only be used a short amount of times, because after a while the print of the wood gets less visible.

(P50: Wood structure surface)

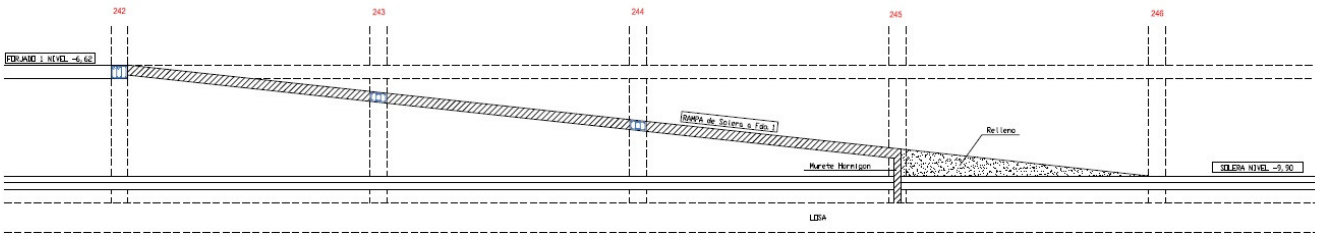
(P51: Wood structure molds)

- Ramps:

To make access to the different cellar levels by use of vehicles, they made ramps. In total there are 3, 2 inside and 1 outside. The ones inside are for the use of the parking area. The one outside can be used for loading and unloading materials at the access point of the sport center. All ramps are located in block 2.

Every ramp has a thickness of 30cm and was constructed with a dry concrete to prevent the concrete from floating away.

Before the concrete is totally dry they make nerves into the surface. This gives more grips.



(P52: Section of the ramp)

(P53: Wood molds, ramp) (P54: Nerves into the surface for more grip)

- Stairs:

A very important phase I managed to see was the construction of the central staircase and the access staircase to block 2.
The central staircase links the several levels from both blocks to eachother.
All stairs have been constructed in situ. This was a time taking process as it took over one week to finish one level. The precision of these elements had to be very precise, because little changes would be visible very quick.

The stairs were always constructed out of reinforced concrete supported by a metal mold with the same form from the stairs. These metal molds only have a visual aspect and are not used to make the construction more strong.
Eventually they will use marble to make the finishing of the stairs.

(P55: Central staircase steel mold)

(P56: Central staircase wood formwork)

7.3.2 Wood structure

On top of the inclined beams of great height comes the wood structure for the curved roof. These are very large beams that go from one point of the sports hall to the other side. The beams are laminated, that means it's formed by adding several layers of wood.

The project is situated on a hill; this means that it's very difficult to supply materials from this size. They had to deliver the beams with a telescopic crane since a street below. The beams are kept in place by steel shoes.

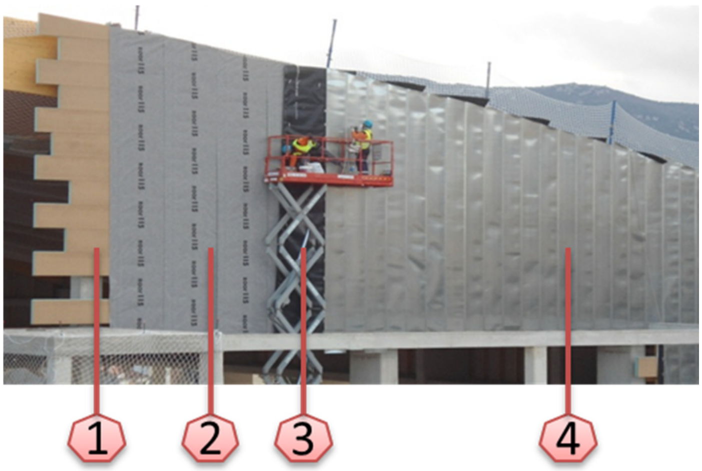
(P57: Telescopic crane used to lift the wood beams)

(P58: Wood structure, sports hall)

7.4. Covering sports hall

The covering of the roof/sides has the following layers:

- 1) Sandwich panel HERAKUSTIK (15mm; Extruded polystyrene 80mm, DM 10mm+DM 10mm)
- 2) Breathable film 120gr (1'5 x 50) DROOFSTR
- 3) Draining sheet (2x20) (naps) DREN
- 4) Zinc.



(P59: Exterior roof side coverage, sports hall)

(P60: Detail draining sheet, naps)

7.5. Facades

In total there are 3 different types of facades.

- <u>Type 1 (40cm):</u>
  This is a two ply front, with a width of 40cm and contains the following elements.

  1) Integral insulation (fiberglass) 6cm with a final surface of outside plaster.
  2) Double hollow brick ½ foot thick. Carrying the structure.
  3) Polyurethane insulation, 5cm thick.
  4) Air chamber
  5) Double hollow ceramic brick of 7cm thick
  6) Inside Plastering

- <u>Type 2 (54cm):</u>
  This is a two ply front, with a width of 54cm and contains the following elements.

  1) Integral insulation (polystyrene plates) 6cm thick, with a final plaster structure.
  2) Double hollow brick ½ foot thick. Carrying the structure.
  3) Air chamber
  4) Double hollow ceramic brick ½ foot thick.
  5) Inside plastering

- <u>Type 3</u>
  1) Sandwich panel HERAKUSTIK (15mm; Extruded polystyrene 80mm, DM 10mm+DM 10mm)
  2) Breathable film 120gr (1,5 * 50) Droofstr
  3) Draining sheet (2 * 20) (naps) Dren
  4) Zinc

7.6. Pavements

- Marble flooring on the stairs at staircase 7 and the lobbies.
- Terrazzo flooring on the commune areas.
- Clinker, reinforced with murfor each 5 rows in the areas P1 (first level) and PB (ground floor)
- Porcelain flooring
- Flooring gym, 54mm (cachou 19mm, marino 15mm + 12, cork)
- Flooring sport hall (Gerflor, 9mm taraflex)
- Plasterboard plates
- Acoustic panels in the gym area (Heraklith pb)
- Glazed tile cladding in the changing rooms.

7.7. Tiling

Placing of the tiles in the bathrooms.

(P61: Tiling)

8. Cellar

8.1. Introduction

In point 7 i made a global explanation from every phase done at the construction site. In this part of my final project I want to explain one of these phases a bit more detailed. I chose to explain the phase where they constructed the cellar and more specific the part where they have built the diaphragm walls.

8.2. Terrain discription

The terrain is located in an urbanized area in the town of Alcoy, behind the UPV-campus building “Carbonell”. The previous use of this terrain was parking area. To decide what type of cellar they would construct they had to keep in mind the steep slope to the north and the sharp hillside slope in the west, whose base runs to “Alicante Street” and which contains several buildings.

The site used for the excavation of the cellar has an approximate area of 3800m², which will be fully occupied by the building, consisting, a basement in block 1 and three basement levels in block 2.

Before any realization was done they made a visit to the project site, to gather all information of interest for the realization of a terrain study.
At that time the area housed the campus parking area that was divided into various platforms from different heights to soften the general slope.

This study was used to investigate the nature of the subsoil, and determine the geotechnical properties of the existing materials. The results of these studies are required to establish the dimensions, the support, and the type of foundations of the cellar. The ground considered on the site is ground group **T1**.

T1: Compact rock, cemented soil or very dense granulate.

8.3. Geotechnical study

The geotechnical study that started in July 2010, in which they studied the ground bearing capacity according to the dimensions, was done to make sure no groundwater would enter the site. They have detected free water in three of the four tests located at the basement area. They eventually focused on survey S-6, because this was the area in which the water appears to be located less deep.
The following table shows the depths of the water table during several visits that were made.

	11/06/10	08/07/10	22/07/10	13/09/10
S-4	22.00	21.00	21.	20.85
S-5	17.50	15.75	17.25	15.50
S-6	12.20	12.20	12.23	11.15
S-7	---	12.20	13.20	13.20

(P62: Water table)

Because of the higher water level in survey S-6 they made provisions for being able to avoid the need of bentonite slurry in the excavation of the diaphragm cellar walls. Bentonite is a liquid substance used to prevent ably hold the surrounding ground and water during the excavation of a wall before concrete is added.
If the water table isn't higher than the depth of the construction it's not needed to use this substance. To lower the water level in survey S-6 they used a piezometric pipe, which allows to temporary lower the water level by use of a pump. This tube was also used as a guide to ensure the water depth was convenient at that time.

Another important conclusion made because of the geotechnical study is the determination of the dimensions of the diaphragm walls.
This has been tested by a horizontal ballast module, considering that the materials traversed by the screens are largely clay. According to the formula of Terzaghi (1999.80 t/m^3) the screen has a width of 0.50m.

8.4. Diaphragm Walls.

8.4.1 General

The increasing use of space in urban areas in the recent years has led to an increasing demand for underground structures like, car parks, storage…
This calls for excavations, near or even under existing building or infrastructures. Together with that the required depth and the high demands on vibrations and noise also increased.
For the construction of underground car parks, like at my project in Alcoy, diaphragm walls are typically.

8.4.2 Definition

A diaphragm wall is a permanent water and soil turning construction. They are made by digging a narrow (0.50 to 1.20m wide) and relatively deep trench filled with a substance. The substances mainly are bentonite and cement.

Diaphragm walls are made since the ground level by a trench to be excavated to a predetermined depth. In order to prevent collapsing they use the bentonite substance. Before digging can be started, they provide guide walls to the ground surface. After the trench is completely excavated they place reinforced steel cages. Once in place they replace the bentonite by concrete.
After the concrete has dried they can start the excavation of the construction area.

A diaphragm wall can be used in certain construction activities, such as:

1) As a retaining wall
2) As a cut-off provision to support deep excavation
3) As the final wall for basement or other underground structure (tunnel and shaft)
4) As a separating structure between major underground facilities
5) As a form of foundation

8.4.3 Equipment

For the excavation of the trenches, for example, Kelly-grippers (clamshells) are applied. These grippers are attached to a long rod.
There is also a second type of gripper that contains a cable suspension.
It is very important that the claws can be closed at the same time.
In Alcoy they used the type that contains a cable.

(P63: Kobelco slurry wall excavator)


(P64: Slurry wall excavator claws)

8.4.4 Why diaphragm walls?

Diaphragm walls are widely used when the sheeting should be Earth and water-turning. They have the advantage that they can take large bending moments and that they can also serve as the foundation for a large part of the structure, because they are deep in the ground.
The execution speed is important. The diaphragm wall technique is not the cheapest, but because of the time savings it can sometimes be better to choose a more expensive technique.

The diaphragm walls provide a drastic shortening of the construction time because they already achieve the final wall of the underground construction before the earthworks start.
Diaphragm walls have the advantage that they already have a good looking surface after the excavation. Normally they get cleaned with water under high pressure. They can also cut away or sandblast the surface to have a better finished product. In Alcoy they used a cutter to make the surface looks the same in all areas.

This wall technique is vibration free and therefore recommended for wall constructions near buildings.
The noise made by the use of a diaphragm wall is minimal to the environment.
By applying the necessary anchors they can build a completely free of struts wall, what makes it easy to dig out over their entire height. This simplifies the construction process.

8.4.5 Panel dimensions

Conducting the soil was very important to enable:

1) The determination of the dimensions of the diaphragm wall structure (depth and thickness).
2) The determination of the slot length (or length of the diaphragm wall panel);
3) To determine the stability of the excavation in which the diaphragm wall is part of.

This means that by calculations, the dimensions of the panels can be determined to balance the horizontal and vertical strength of the deep wall structure.

<u>Panel height:</u>

The depth of insertion of the panels is generally determined by the following features related to the design:

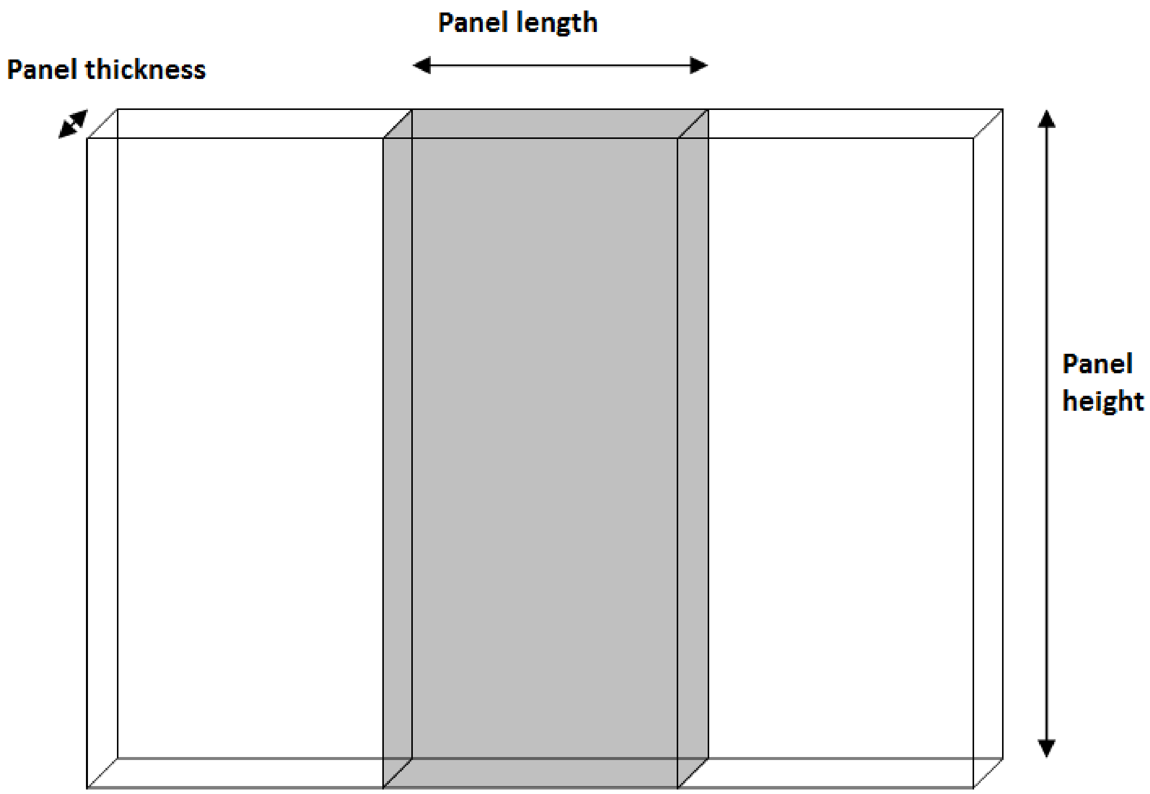
1) The horizontal earth pressures against the wall.
2) The minimum depth to which water resistance should be guaranteed.
3) Vertical load.

Incidentally, the upper 0.5 to 1.5 m of concrete in all cases is of less quality and therefore practically always demolished and replaced by a new concrete beam.

Panel thickness:

The panel thicknesses in case of diaphragm walls are relatively large.
In cases where the deep wall serves an underground space, like the parking area in Alcoy, then the thickness is also an important influence on the useful available surface of this space.

Because diaphragm walls are often applied in areas where the available space is limited, the project boundaries are in most cases fixed.
The panel thicknesses were already determined at an early stage and there is also the desire to keep this as low as possible. In Alcoy the panels have a thickness from 0.50m.



(P65: Panel dimensions)

8.4.6 Process

<u>Preparation works:</u>
During the whole diaphragm wall process they made use of different machines. To have the right machines at the right time in the right places the coordination by the chief was very important. After the leveling of the site was completed, the execution of the diaphragm walls could start.

Before the actual excavation works began they had to study the panel plan.
On this panel plan you could find the order of excavation, the concrete strength, reinforcement and necessary tie rods, the places where the anchors had to come...

(P66: Study of the panel plan)

The dimensions of the panels were slightly different. The dimensions should not be too large since it should be possible to concrete the full panel without any concrete begins to harden. In practice this means that a panel should be perfectly poured within 4 to 5 hours.

They also had to keep in mind the site installation: how they will excavate and where the access points to the site will be for the excavators and trucks to transport the ground.

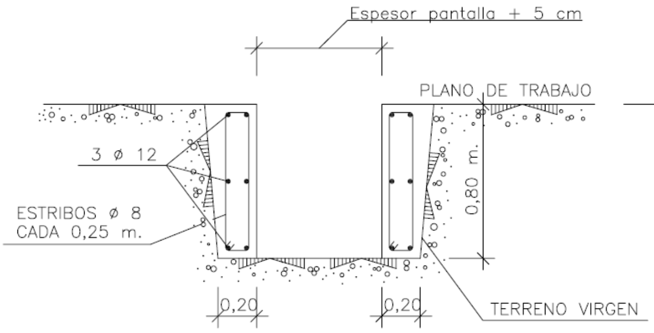
Guide walls:

Before the heavy excavators began their work, it was necessary to construct guide walls. The guide walls ensure that the work goes faster and easier. After the works the walls have to be removed.

The guide walls have the following functions:

1) Guidance for excavator at the start of the work;
2) Storage of the bentonite mud: at the start of the excavation. In Alcoy there was no need to use this substance.
3) Lateral retaining walls of the top layer of the site. The guide walls ensure that the slots are closed and not collapse under the weight of the excavators on the edge of the excavation;
4) After the excavation the walls provide the necessary guidance and accuracy when placing the reinforcement cages and the joint molds.

The dimensions of the walls depend on the size of the work. In Alcoy they have a thickness of about 20 cm and a height of 80cm. They are constructed at the construction site itself. On one side against the ground and on the other side against a formwork. They used a formwork module, which could be used again and again and that guarantees the exact dimensions of the guide walls.
The module is fitted with a crane at the right place and set at the right width.
The concrete is poured and after curing, the formwork is moved.
The formwork can easily be removed by bringing closer the vertical walls of the modules. As reinforcement for the support of the walls they used a light reinforcement from diameter 12mm.



(P67: Guide walls)

(P68: Guide walls Alcoy)

Guide wall excavation:

After the walls dried, they were able to excavate the ground from between the guide walls. This had to happen with great precision, because this could have catastrophic consequences. The excavation couldn't happen in one time, because of the great length. That's why they excavated in stages with every time an unexcavated zone in between.

(P69: Excavation between the guide wall)

Reinforcement:

After the digging the reinforcement could be arranged in the slots.
The reinforcement cages were lowered by using a crane. The reinforcement is necessary to be able to absorb the tensile forces as concrete can't absorb pull forces. The reinforcement cages were supplied as shown in the figure.
Because of the great depth of the walls they had to adjust several cages on the construction site.

- Steel: B500 SD

(P70: Steel reinforcement cages)

There has also been taken into account the ratio of the smallest mesh size compared to the biggest grind size. If the ratio is too small, the flow of the concrete is in danger and there is a chance to have gravel nests.

Concreting:

Supply of concrete was needed in large amounts. The more fluid the concrete stays during the casting process, the better the end result will be. The company who concreted the work, held several concrete mixers ready to have a constant supply. To achieve the best possible quality it's better not to make the horizontal area per unit too large.

Breaks in the process over a long period can have great consequences.

- Width: 0.50m
- Concrete: HA-30/F/IIa + QA

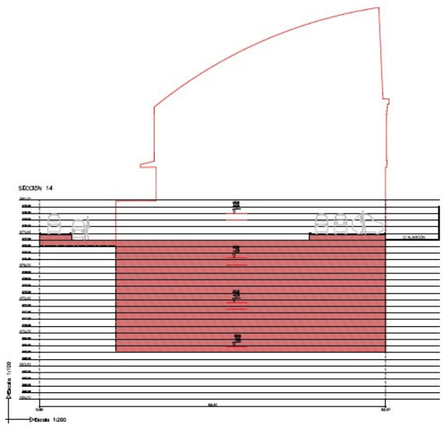
Demolition top layer:

Like I explained before, the upper 0.5 to 1.5 m of concrete in all cases is of less quality and therefore practically always demolished and replaced by a new concrete beam. The replacement was done by use of a formwork built at the construction site as you can see in the following picture.

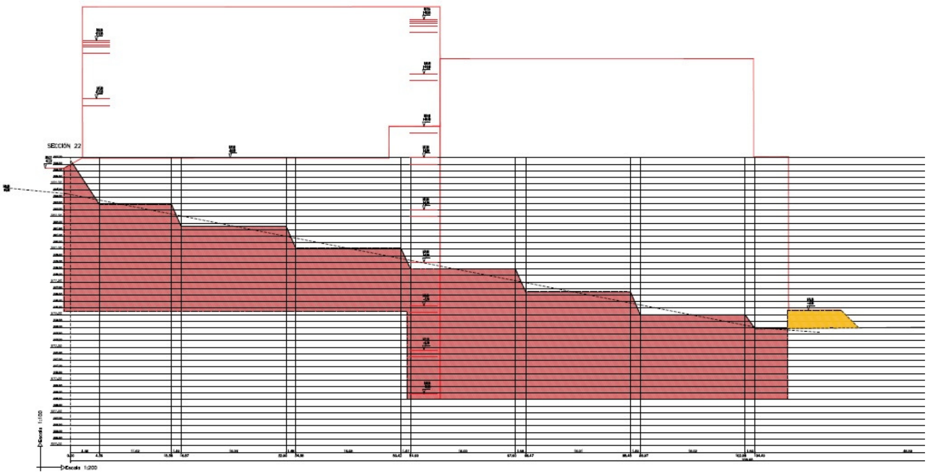
(P71: Demolition and replacement of the top layer)

8.5. Excavation

The excavation on the site was necessary for the construction of the basement, that contains one underground floor in block 1 and three underground floors in block 2. The depth of the excavation varied due to the slope that was present in the area. Eventually they excavated a depth from around 12.00m in the south part, about 10.00m at the north end, and around 13.50m in the junction area between block 1 and block 2.
To show the depth of the area they have made different sections of the site that show the excavation levels. In total there were made 22 of these sections, 21 sections over the width and 1 section over the length of the construction site. The following images show sections 14 and 22 as an example.



(P72: Section 14)



(P73: Section 22)

Like I explained before in the phases, the first they had to do before any excavation could be done was to remove all the asphalt and pavements from the existing parking area by use of excavators with jack hammers. They removed the top layer from the entire area over a depth from 25cm.
In total they removed around 2652.15m³ of top layer over that depth.

After they removed the top layer they started to excavate the ground. This was done in a several stages which they decided before. As I learned in my subject “Equipos de obra” this has to be done very precisely, because every part of the team needs to have access to the different levels for being able to remove the ground. To make the access they build ramps with the existing ground. These ramps changed several times during the excavation process.

During my visits they explained me the several stages they have done to excavate the cellar. To have a visual aspect about the stages they gave me a video that was used to present the project. In this video they explained the exact order of the excavation. In total they removed about 44259,40 m³ of ground.

(P74: Excavation)

8.6. Anchors

Due to the depth of the excavation, the soil pressures alone are not sufficient to keep the deep walls in balance. So it Is required to have extra lateral support. There are some possibilities. They can make use of ground anchors or of struts. In some cases, the structure is used to set itself as lateral support. In Alcoy they used ground anchors to give the lateral support.

Ground anchors are anchoring elements for construction and excavation walls. They are set in place without the need of any excavation in the back of the existing installed wall. The anchoring element consists of a high-quality steel rod or wire bundle, which at one end is formed in a high-pressure shaped cylinder of cement grout. The ground anchor takes up pulling forces. Ground anchors can be used as permanent and temporary construction elements. The permanent anchors are provided with a corrosion protection.

The installation of ground anchors can begin immediately after a partly or whole excavation has been done. Before there takes place an excavation to about 0.50m below the level of the future made anchor row.
Through a hole in the diaphragm wall a drill has been set with a predetermined slope into the soil. The drill pipe is inserted with a drill equipped with a hydraulic hammer. When the drill pipe has been inserted to the desired depth, the anchor rod or wire bundle could be inserted into the tube.
After this, the space between the drill tube and the anchor rod is filled with cement grout, a mixture of cement and water added under pumping pressure. This results in a very large cement stone, called the anchor body at the front of the anchor. This anchoring body may have a length of four to ten meters, depending on the transferring load and the quality of the ground.

Once the anchoring body was formed, the tube was fully withdrawn.
The upper side of the anchor now comes through the diaphragm wall.
After sufficient hardening of the cement grout the anchor is tensioned on a supporting plate.
Each anchor is checked for its pull.
Due to the tension the major part of the elastic stretch is also removed from the anchor, this makes that the movements of the wall structure will remain limited.

(P75: Anchoring)

(P76: Tension anchors)

8.7. Floor connections

There are several possibilities to make the floor connection with the diaphragm wall. However the preferred option was to glue the reinforcement into the wall to make the connection, because obstacles in the reinforcement make risks for the flow of the concrete between the several nets.
This can create spaces in the concrete what can result in leakages.
A negative point of gluing is the limited anchorage length that can be realized.
The different types of floors have been explained before (8.3 Structures)

(P77: Floor connection, Hilti components)

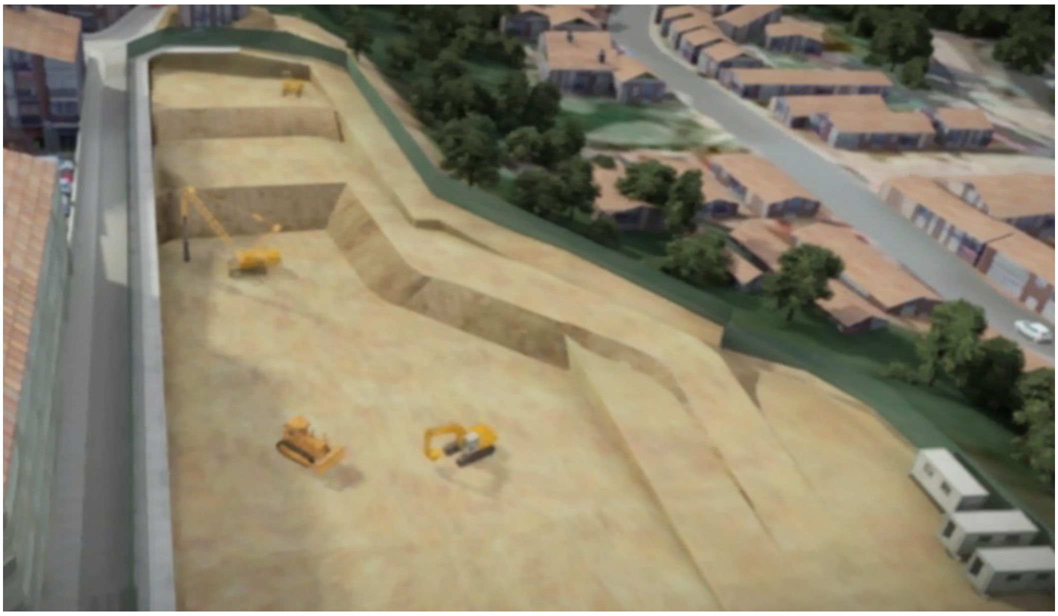
(P78: Glued reinforcement)

8.8. Phases to construct the cellar

1) Excavation of the top layer (25cm), containing asphalt, pavement, trees, …

(P79: Excavation of the top asphalt layer)

2) Excavation of the first stage in the part situated at block 1.
Since this stage they excavated the ground towards block 2 by providing several ramps. The depth they excavated is not the ultimate depth they have to reach. The ultimate depth will be reached after the construction of the diaphragm walls.



(P80: Excavation part 1)

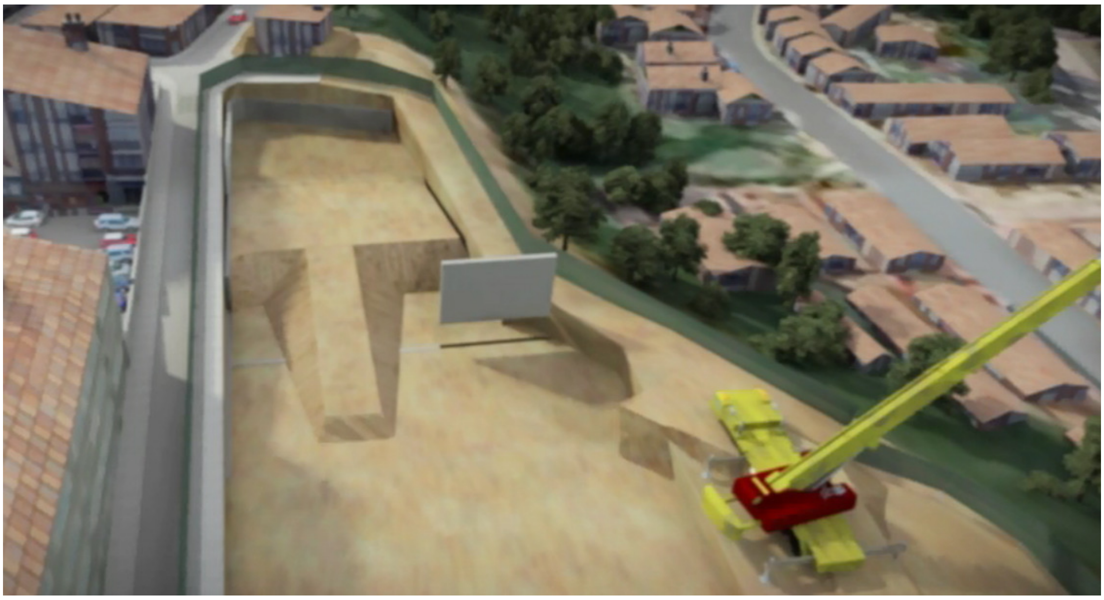
3) Construction of the guide walls used for the construction of the diaphragm walls.

(P81: Construction guide walls)

4) Construction of the diaphragm walls situated in block 1.

(P82: Construction of diaphragm wall block 1)

5) After the construction of the diaphragm walls in block 1, they were able to excavate the ground until a deeper level. This excavation went together with the construction of new ramps and the provision of anchors.



(P83: Excavation part 2 + ramps)

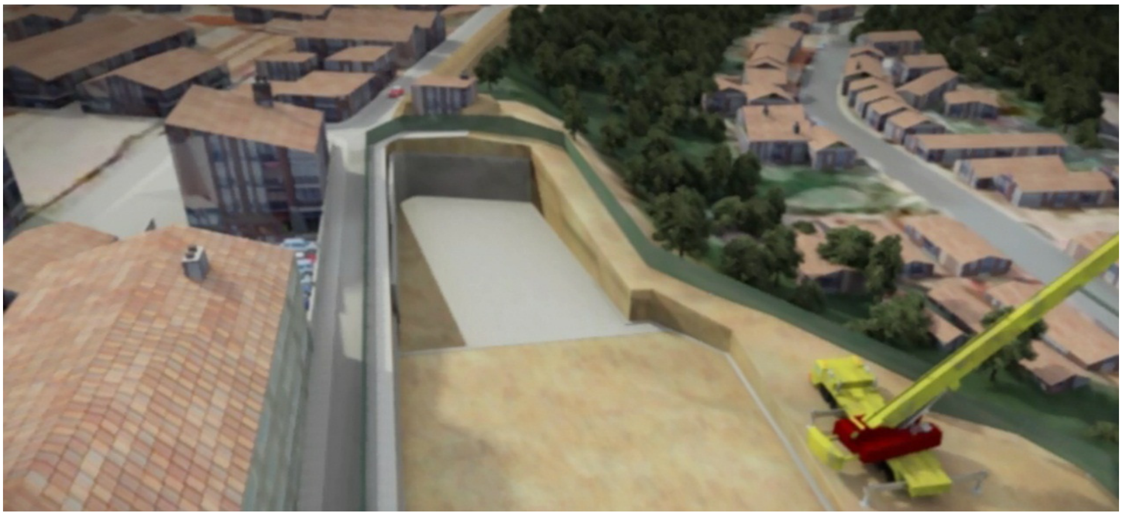
6) Construction of the diaphragm walls situated in block 2.

(P84: Construction of diaphragm walls in block 2)

7) Excavation of the ground in block 1 till the final depth. (Foundation floor)

(P85: Excavation part 3, till final depth in block 1)

8) Construction of the foundation floor in block 1.

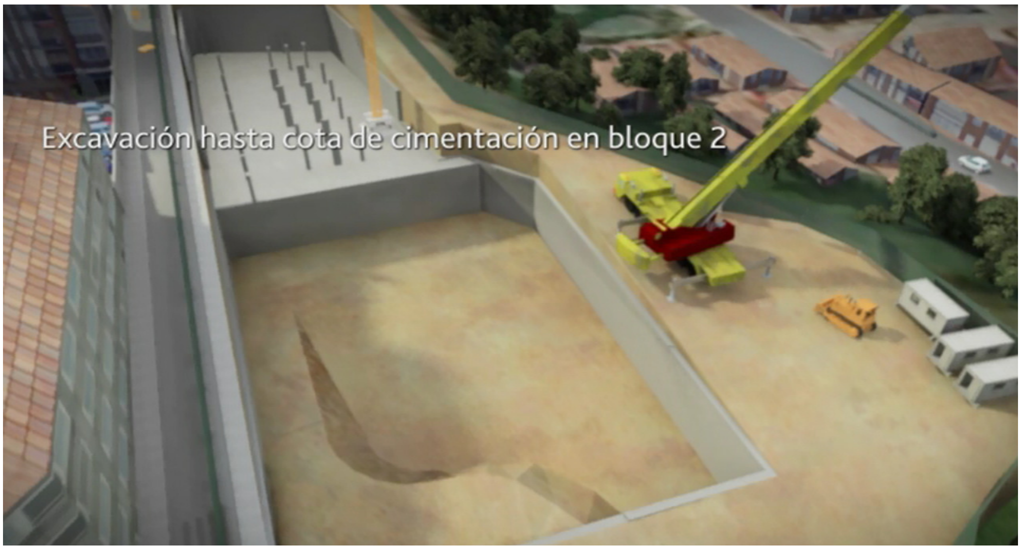


(P86: Construction of the foundation floor block 1)

9) Excavation of the ground until a deeper level in block 2.
At this level they made the provisions for the anchors to hold the diaphragm walls in place. Because of the big dimensions of the project they were able to work in different places at the same time. For example, while they excavated the ground in block 2, they constructed the tower crane and the columns in block 1.

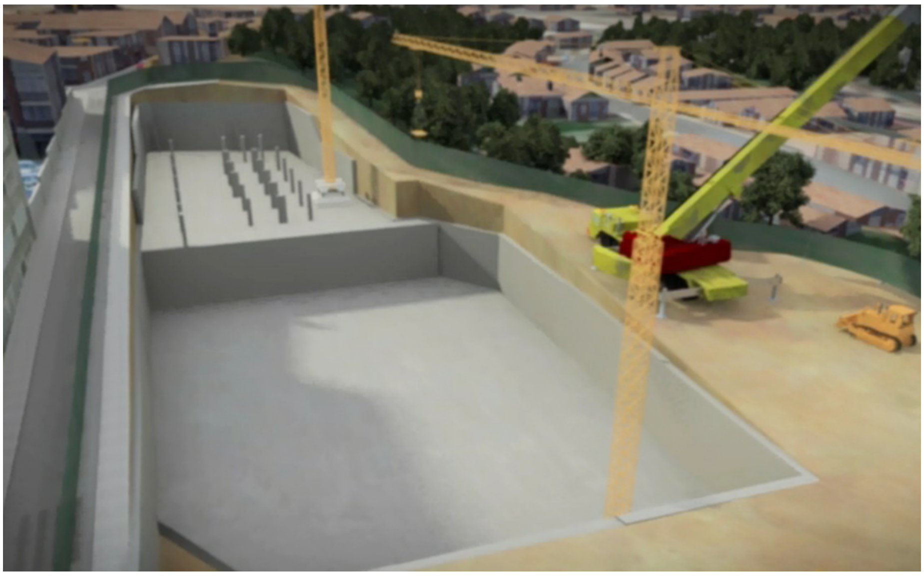
(P87: Excavation part 4 till anchors in block 2)

10) Excavation till the foundation floor level in block 2.



(P88: Excavation till foundation floor in block 2)

11)Construction of the foundation floor in block 2. After the foundation floor was constructed they have set up the second tower crane located in block 2.



(P89: Construction of the foundation floor in block 2)

9. Spain – Belgium

At last I would like to make a comparison between Spain and Belgium about the way they work in construction in both countries.

Timetable:

Already the first day I noticed the first difference.
In Belgium, we start around 7.00 at the construction site, at the site in Alcoy they started at 8.00. This is very strange because we usually start sooner because of the daylight. It also surprised me that they don't start sooner due to the warmer climate.
In Belgium we take a break in the noon at 12.30 for eating. In Spain they usually take a break around 15.00, I had to get used to this difference.
I think these timetables aren't used by all companies and depend on several factors chosen during the phase of execution.

Climate + wall construction:

A warmer climate automatically brings a different way of insulating.
Once the structure is ready they start with the masonry. This is the same in both countries, but the difference takes place in the way they construct the masonry.

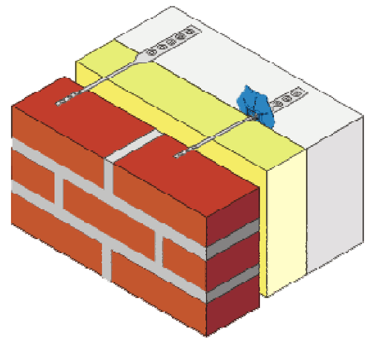
	gemiddelde maximum temperatuur (°C)	gemiddelde minimum temperatuur (°C)	gemiddeld aantal uren zon per dag	gemiddeld aantal dagen neerslag per maand	gemiddeld aantal mm neerslag per maand	gemiddelde zee temperatuur (°C)
januari	5	0	2	20	💧💧💧	7
februari	5	0	3	16	💧💧	6
maart	8	2	4	19	💧💧💧	7
april	12	4	5	15	💧💧	8
mei	16	8	7	17	💧💧💧	10
juni	20	12	7	14	💧💧	13
juli	22	14	7	14	💧💧💧	16
augustus	22	13	7	15	💧💧💧	18
september	19	11	5	15	💧💧💧	18
oktober	15	7	4	17	💧💧💧	15
november	9	4	2	20	💧💧💧	12
december	6	1	2	19	💧💧💧	8

nihil = 0-5 mm • 💧 = 6-30 mm • 💧💧 = 31-60 mm • 💧💧💧 = 61-100 mm • 💧💧💧💧 = 101-200 mm • 💧💧💧💧💧 = meer dan 200 mm

	gemiddelde maximum temperatuur (°C)	gemiddelde minimum temperatuur (°C)	gemiddeld aantal uren zon per dag	gemiddeld aantal dagen neerslag per maand	gemiddeld aantal mm neerslag per maand	gemiddelde zee temperatuur (°C)
januari	16	6	5	11	💧💧	14
februari	17	7	6	10	💧💧	13
maart	19	8	7	10	💧💧	14
april	20	10	7	9	💧💧	15
mei	23	13	8	8	💧💧	17
juni	27	17	9	5	💧	21
juli	30	20	10	2	💧	24
augustus	30	20	9	3	💧	26
september	28	18	8	5	💧💧	24
oktober	24	14	6	8	💧💧💧	21
november	19	9	5	10	💧💧	18
december	16	7	5	11	💧💧	15

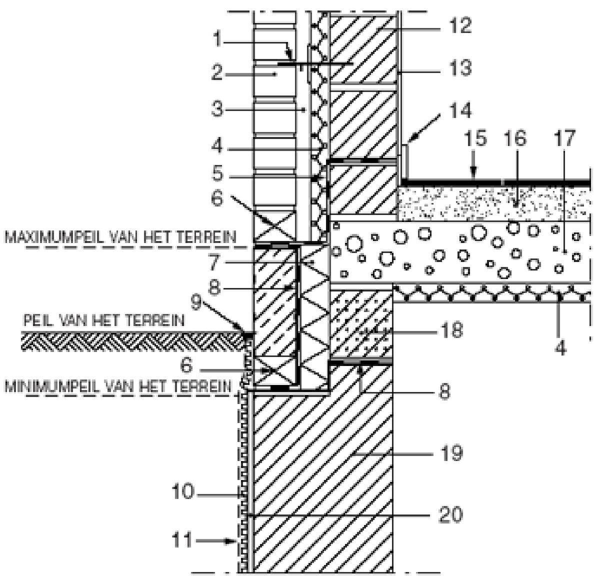
nihil = 0-5 mm • 💧 = 6-30 mm • 💧💧 = 31-60 mm • 💧💧💧 = 61-100 mm • 💧💧💧💧 = 101-200 mm • 💧💧💧💧💧 = meer dan 200 mm

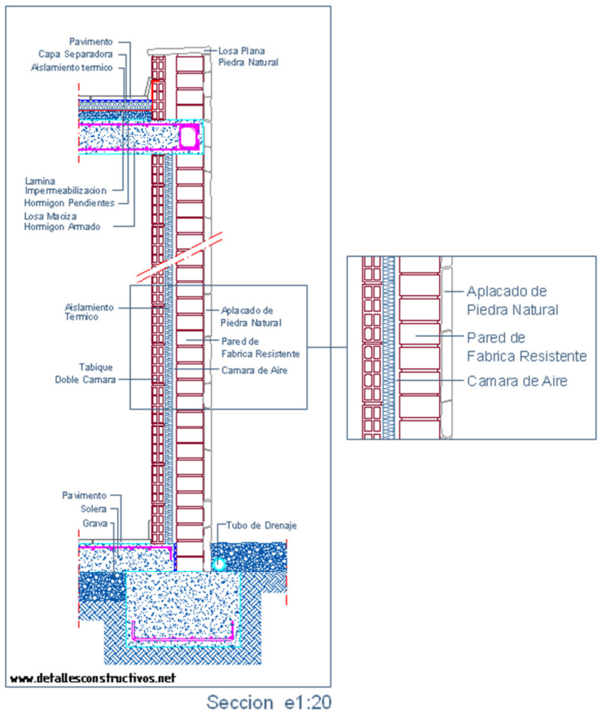
In Belgium we first build the inner wall, we add insulation on that wall by use of the provisions made while construction. Later we build the façade at a certain distance from the inner wall so we create an air chamber between both leafs.
The best insulation is stationary air.



(P90: Insulation)

In Spain they work since the inside of the building so they can largely work in the shadows.
Since inside, they first construct the outer leaf of the cavity wall which of course includes the openings for windows and doors. Once the outer leaf is ready they add the required insulation on the outer leaf and construct the inner leaf.
Because of the sunny Spanish climate they try to keep the heat as much as possible outside and therefore they apply the insulation on the inside of the outer leaf of the wall. In Belgium we insulate the inner leaf to keep the heat mostly inside the building.





(P91: Belgian wall construction) (P92: Spanish wall construction)

In Belgium the main weight of the construction is guided since the inner wall towards the foundations, while in Spain it's guided since the outside wall (façade). The several floors rest on these bricks. We also make a lot use of aerated bricks (Ytong) because of the good thermic capacity.

Since some years we also construct more and more "low energy" houses. These are houses mainly constructed out of wood a structure with a big amount of insulation. These houses have a very low demand of energy to produce heat which makes it very interesting to save on energy costs on long term.

(P93: Aerated brick house)

(P94: Low energy house)

<u>Carpentry:</u>

Another difference I noticed at the construction site in Alcoy was the way they make provisions for the future carpentry. Here in Spain they make wood pre-marks witch they set in place before they construct a wall. Later they construct the wall around these wooden molds. These pre-marks already have the needed dimensions from the future doors or windows.

In Belgium we don't use pre-marks, but we use wall blocks made out of a mix from wood and cement. This makes it easier to later add the carpentry to.

(P95: Carpentry Spain)

(P96: Carpentry Belgium)

<u>Rainwater tank:</u>

Because of the different climate, and because in Belgium we have more rain than in Spain, we make use of this free water.
In every new building with outside space we build underground rainwater tanks. Several tanks from 20.000 L are not strange in Belgium.
For example in my house we have 2 rainwater tanks from 15.000 L. These tanks fill up when it rains because we guide the water since the roof by use of plastic pipes attached to the roof. The water can be used to shower with, to wash, to flush the toilet, to wash the car…, but not to cook with. The best about all this is that it's completely free.

In Spain this appears to be used a lot less frequent.
In Alcoy tough there is a water recovery tank situated.

(P97: Rainwater tank Belgium)

I hoped to find more differences at the construction site in Alcoy, but eventually there aren't very big differences between both countries.
The cellar that is explained in point 8 was done in exactly the same way than for example in Belgium. Diaphragm walls in Belgium are called "diepwanden". The biggest differences are the construction of the walls and the climate.

10. Conclusions

The conclusions I can make about my final project are that I learned a lot about diaphragm walls. In my previous final project, which I had to make during the first semester in Belgium I explained two different cellar types which I saw at my internship. This makes my final year very interesting, because I'm very interested in that part of a building.

In the previous point "Spain - Belgium" I was able to make a conclusion about the way of construction in both countries. Eventually there isn't a big difference between both countries. There are a lot methods that are done in the same way.

The biggest difference is the wall construction and of course the warmer climate from Spain.

Devolder Lawrence

2012-2013